Some Guidance on the Use of Ceramic Filters

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Introduction

Ceramic filters are a very convenient and cheap way of improving the selectivity of old receivers. The three main manufacturers of ceramic filters, Murata, NTK, and Kyocera, used to offer a wide range of bandwidths, in both plastic and metal cases, with a choice of low, medium, and high stopband performance on 455 kHz, and a much reduced range on 450 kHz. Now, the only company left manufacturing ceramic filters seems to be Murata, and they have drastically reduced the range they offer. It's time to stock up for any projects you've got planned for the future!

The spurious responses of ceramic filters are very often singled out for special criticism. Let me tell you, though, that all filters that make use of mechanical resonance in solid materials suffer from the same problems of unwanted modes. This includes quartz crystal and mechanical filters. None of these filters should be used without additional LC filtering, such as IF transformers, to attenuate the spurious responses to acceptable levels. The main drawback of ceramic resonators is their relatively low Q, which causes rounding of the passband edges and a limitation on the minimum achievable bandwidth. The Q can be rather variable in production as well, and at 455 kHz it can be anything from under 1000 to over 3300. The Q of mechanical filter resonators is not much better than the best ceramic resonators, but they are not so variable. The Q values of quartz crystal resonators are very much higher than either of these at 455 kHz, and they can be used to produce filters with lower insertion loss and less passband rounding, or narrower bandwidths. However, although limited in application by their Q, the great advantage of the ceramic filters that can be produced with reasonably low insertion loss and passband rounding is their size and cost. We're lucky because they cover the range of bandwidths used on AM quite comprehensively at 455 kHz.

Filter Bandwidths

The bandwidth figures quoted by manufacturers are always the minimum bandwidth likely to be found in production. A typical bandwidth for any ceramic filter is usually much greater than these minimum figures, except for the CFJ455K14 and K15 SSB filters, which appear to be selected from the CFJ455K5 production spread, and are usually within about 100 Hz of the specified bandwidth. The K5 filters available to hobbyists are generally 2.7 to 2.9 kHz bandwidth at the –6dB points. I think this is because all the 2.3 to 2.7 kHz filters have been selected out from the production run for the K14 and K15 versions used in Japanese SSB equipment. The CFJ455K8 is a narrow version of the K5, and has a typical –6dB bandwidth of 1.7 kHz ± 100Hz (specified as a minimum of 1 kHz). These filters make good CW search filters, or can be used on receive for SSB when the going gets really tough! The cheaper CFM455J1 filter, which is often used for SSB reception in Japanese general coverage receivers, is specified as a minimum of 2.6 kHz bandwidth at –6dB, but I have yet to find one that is less than 3.7 kHz, and I have measured at least 7 of them to date. These can make very good narrow AM filters for situations where the adjacent channel interference is bad. Filters for AM bandwidths are very often about 1 to 2 kHz wider than the mini-

Murata	NTK	Min. BW(-6dB)	Term. Imp.	Ins. Loss	Typ. BW(-6dB)	Stopband
CFG455I	SLF-D4	4kHz	2k	7dB	5.2kHz	85dB
CFG455H	SLF-D6	6kHz	1.5k	6dB	8.5kHz	85dB
CFG455G	SLF-D8	8kHz	1.5k	6dB	10.5kHz	85dB
CFJ455K8	n/a	1.0kHz	2k	8dB	1.7kHz	90dB
CFJ455K5	n/a	2.4kHz	2k	6dB	2.8kHz	90dB
CFK455I	CLF-D4	4kHz	2k	8dB	n/a	80dB
CFK455H	CLF-D6	6kHz	2k	7dB	n/a	80dB
CFK455G	CLF-D8	8kHz	2k	6dB	n/a	80dB
CFL455I	n/a	4kHz	2k	8dB	n/a	60dB
CFL455H	n/a	6kHz	1.5k	7dB	n/a	60dB
CFL455G	n/a	8kHz	1.5k	6dB	n/a	60dB
CFM455J1	n/a	2.6kHz	2k	6dB	3.7kHz	70dB
CFM455I	LF-C4	4kHz	2k	7dB	6kHz	50dB
CFM455H	LF-C6	6kHz	2k	6dB	8kHz	50dB
CFM455G	LF-C8	8kHz	2k	6dB	9.5kHz	50dB
CFS455J	LF-D2?	3kHz	2k	8dB	5kHz	95dB
CFS455I	LF-D4	4kHz	2k	8dB	n/a	95dB
CFS455H	LF-D6	6kHz	2k	7dB	n/a	95dB
CFS455G	LF-D8	8kHz	2k	6dB	9.5kHz	95dB
CFX455I	n/a	4kHz	2k	8dB	n/a	70dB
CFX455H	n/a	6kHz	1.5k	7dB	n/a	70dB
CFX455G	n/a	8kHz	1.5k	6dB	n/a	70dB
CFW455IT	LF-H4	4kHz	2k	6dB	6.2kHz	50dB
CFW455HT	LF-H6	6kHz	2k	6dB	8.1kHz	50dB

Table 1: Data on 455 kHz ceramic filters.

mum specified figure in the manufacturer's data. NTK LF-C6 and Murata CFS455H filters, which are specified as a minimum of 6 kHz bandwidth, are quite often 8 kHz wide at the –6dB points, but the CFS455I and CFG455I filters (minimum 4 kHz) are usually only 5.1 to 5.3 kHz wide. If you want a filter that is, typically, slightly over 6 kHz wide, it's quite a problem to find one. The only one I've found during the many years I've been looking is the CFW455IT, which doesn't have a great stopband performance, but is adequate and very handy for improving old receivers with an excessive –6dB bandwidth. The best narrow AM filter I've ever come across is the CFS455J, which is specified as a minimum of 3 kHz bandwidth at –6dB, but is actually nearer 5 kHz, and has a –60dB bandwidth of 7 kHz! This is a very good filter, but a bit on the narrow side for good quality AM.

Recommendations

To improve the selectivity of old receivers that are very broad, I would recommend the use of the CFW455IT for those who want slightly more than 6 kHz bandwidth at the –6dB points, and one of the 'H' suffix Murata filters from the CFS, CFG, CFL, CFK, CFX, or CFM ranges for those who want 8 kHz. I haven't tried the NTK equivalent of the Murata CFW455IT, but the equivalents of the Murata 'H' bandwidth filters are designated '-6' by NTK. For receivers which have a good "on the nose" bandwidth for AM, and only require some help in the transition region and a bit of additional stopband attenuation, the typically 8 kHz, or 10 kHz wide filters from the nominal 6 kHz, or 8 kHz minimum bandwidth range are a good choice. Then, the original 6 kHz bandwidth is hardly reduced at all, but the steepness of the roll-off in the transition regions

either side of the passband are greatly improved, and the adjacent channel rejection increased tremendously. The NTK LF-C6, Murata CFS455H, CFG455H, CFM455H and CFL455H filters are all good for this application. The CFS455H has the best stopband attenuation. If you want the slightly wider bandwidth filters, they are identified by the suffix 'G' in the Murata range and '-8' in the NTK range of ceramic filters. For example, the CFS455G is a nominally 8kHz bandwidth (minimum) filter with a typical –6dB bandwidth of 9 to 10 kHz. I've put together all the information I've gathered on ceramic filters over the years, and also added information from my measurements of filters I've used in various sets, to produce **Table 1**. There is no column listing the ripple for each filter because Murata seems to state 3dB maximum for all their filters, despite the fact that it usually 1dB, or less. This table lists data on filters that are now obsolete, but are still available from some suppliers and on the surplus market.

Matching New to Old

The natural impedance of ceramic filters is around 1.5 to 2k ohms, and matching transformers need to be used to provide the higher input and output impedances suitable for vacuum tube receivers. If this is done properly, the signal voltage at the grid of the following IF stage will be reduced by only slightly more than the insertion loss of the filter. Don't be tempted to transform down from high impedance at the input of the filter, and then terminate the output with a 2k ohm resistor in the grid of the next IF stage. This may seem a very convenient way of doing it, but the impedance drop to the grid will lose too much signal voltage in addition to the insertion loss, and leave the IF short of gain. You're going to lose IF gain, anyway, by fitting a filter and you can probably afford to lose some without it adversely affecting the receiver performance, but not too much. You must transform down and then up again to maintain the original signal level, minus the insertion loss of the ceramic filter and the matching transformer loss, of course. Resistive terminations are required across the IF transformers at some point so that the filter sees a transformed impedance that looks purely resistive to it over a frequency interval slightly greater than the –6dB bandwidth. This can be done very conveniently using the dynamic resistance of the IF transformer, itself, to provide the terminating resistance for narrow filters, but for the wider ones used on AM the transformer responses need to be widened by damping with an external resistor. Miniature 7 and 10mm IF transformers have values of Q around 80 to 120 at 455 kHz, and this needs to be reduced to 20 - 25 for 6 - 8 kHz filters. They usually have resonating capacitors of 150 to 220pF. This means you'll need to use a turns ratio of around 4 or 5:1 between the main tuned winding and the untuned secondary to feed a ceramic filter with a 2k source or load impedance. Alternatively, you can use a single winding from the 455 kHz IF transformer and capacitively tap the tuned circuit for the required source and load impedances. The latter approach can give you more flexibility, and the capacitor ratio can be tailored to give you the best passband response with a bit of experimentation. The tuned circuit must be reduced in Q to provide approximately the right resistance over a bandwidth slightly greater than that of the filter to get the design passband shape. Remember that you only get close to the centre impedance of a tuned circuit over the middle one-third of the response, so the bandwidth defined by the working Q of the matching transformers must be three times the passband of the filter you intend to fit. Very often the built-in tuning capacitor is hidden in a recess in the base of the IF transformer assembly, and can be removed from the circuit by crushing it with a pair of thin-nose pliers. You need to make sure that you've removed all the

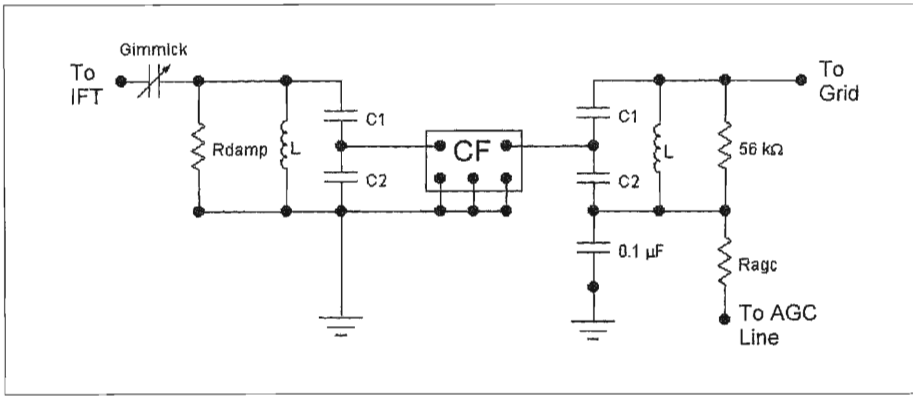

Figure 1: Ceramic filter circuit application.

debris from the crushed capacitor so that there is nothing left to short together, or cause any trouble later.

Circuit Considerations

Very often, the best place to insert a ceramic filter in a vintage receiver is between the mixer and 1st IF stage if there is no crystal filter there. Otherwise, it has to be between the 1st and 2nd IF stages. These stages usually have AGC applied to the grid, but this is no problem because the new output matching transformer can provide a DC path to the grid of the IF stage. You need to disconnect the secondary of the old IF transformer from the grid of the following IF stage where the filter is to be inserted. Unsolder any AGC connections to the lower terminal of the old IF transformer secondary, and ground it. The new input matching transformer can be coupled by a small capacitor to the top of the secondary of the old IF transformer, as illustrated in **Figure 1**. This capacitor only needs to be a few picofarads, and the simplest way to achieve this sort of value, with the ability to vary it, is to use a 'gimmick'. I don't know whether you use the same expression to describe the same thing in the States, but it's just a pair of insulated wires that are twisted together and trimmed to length to get the right small value of capacitance. The values of the coupling capacitor and the damping resistor across the tuned circuit have to be juggled to get the best response from the filter. There is really no substitute for experimentation here! The exact nature of the IF transformer in the plate circuit of the preceding stage is the big unknown. The Q and inductance of the transformer windings, and the degree of coupling can all vary considerably from one design to another, and from manufacturer to manufacturer, so that makes it impossible to give exact values for the coupling capacitor and damping resistor at the input matching to the filter. In addition, when heavy coupling is used in an IF transformer to get a broader bandwidth, the impedance presented to any subsequent stages varies greatly across the passband, making it difficult provide a good match to a ceramic filter by direct connection at this point. In such cases, the coupling to the secondary of the old IF transformer needs to be very light, and the resistor across the new input IF transformer needs to be low enough that it is the one that determines the source resistance for the ceramic filter. The output matching is much less variable and can be predicted quite easily if the turns ratio and tuning capacitance of the output IF transformer are known. For example, to present 2000 ohms to the filter the turns ratio, n, for a working Q_L of 20 would be

$$n = 0.1\sqrt{2\pi fL}$$

The total terminating resistance on the high impedance side should be

$Rt = 2000n^2$.

This terminating resistance includes the coil loss in parallel with the actual grid resistor, Rg (56k ohms in Figure 1). The parallel equivalent of the coil loss, Rc, is $2\pi fLQ_U$ ohms, where Q_U is the unloaded (natural) Q of the new IF transformer winding (normally 80 to 120), and, therefore, the value of the grid resistor, Rg, required to present 2000 ohms to the filter is Rt.Rc/(Rc-Rt). This is also the minimum value of Rdamp in **Figure 1**. Generally, Rdamp will be higher than this value unless the coupling capacitor (gimmick) is very small, and the coupling to the original IF transformer so light that its contribution to the resistance in parallel with Rdamp is negligible.

For capacitively tapping down the IF transformer, you want a pair of capacitors in the ratio of approximately 3.7:1 (C2:C1) and their series equivalent must be within ±10% of the original tuning capacitor value. For 455 kHz IF transformers that have 180pF resonating capacitors, C1 = 220pF and C2 = 820pF are a good choice to obtain the right step down for a loaded Q of 20. In this case, Rg = 56k ohms, as shown in **Figure 1**. For IF transformers that require 220pf tuning capacitors, try C1=270pF and C2=1000pF, initially. You might also have to reduce the 56k ohm in the IF stage grid to 47k ohm to readjust the working Q of the output matching circuit because of the smaller tuning inductance. Don't be afraid to alter the values if you can't get an acceptable passband shape. Rdamp and the grid resistor across the second matching transformer will both have to be reduced if a filter requiring 1.5k ohm terminations is used.

It helps enormously if you have a wobbulator [sweep generator], or spectrum analyser, to check the passband of the whole IF amplifier while you're experimenting with the values of the coupling capacitor and damping resistor. Don't retune any of the old IF transformers, apart from the secondary of the one to which the coupling capacitor (gimmick) is attached. This may require a slight adjustment to allow for the effect of the coupling capacitor, but the others should be left set up as per the handbook alignment instructions. Only the new ones need to be peaked and tweaked for the best passband response after the ceramic filter and its matching circuitry have been installed. If you don't have a wobbulator, spectrum analyser, or even an 'S' meter to indicate the filter response as you tune through a steady carrier, then you can always attach a VTVM to the AGC line to assess the flatness of the IF passband. There are usually simple alternatives to expensive test equipment. It's just that it's not as accurate, and often takes a bit longer without the right equipment. The grid matching transformer decoupling capacitor is shown as 0.1µF in **Figure 1**, but may need to be reduced to 0.01µF if the AGC action is slowed too much by using the larger value. Don't go lower than this, though, as the reactance of the decoupling capacitor must be very small compared with 2000 ohms at 455 kHz.

Shielding

The most sanitary way to add the filter and matching circuitry, RF-wise, is mounted on a specially etched PC board. In order to get the best stopband attenuation from the filter, you need to make sure that components on the input side can't 'see' components on the output side. You can use the metal IF transformer cans and the metal filter case to do this on top of the PC board. Some additional brass shimming, or PC board, might also be required either side of the filter to block input-output coupling. I like to put some screening right over the input pin of the filter on the underside of the board as well as leaving some

grounded copper track between input and output. The board also needs to be grounded carefully with low inductance ground leads, or through metal mounting pillars to the chassis of the receiver. The outer from coaxial cable makes good grounding leads. If you use copper strip board instead of a purpose made PC board to carry the filter assembly, you can use the outer from RG174 miniature cable to bond adjacent copper strips together to form larger grounding areas to minimise the ground inductance for the signal return paths and improve screening.

Results and Final Remarks

The effect of installing a modern ceramic filter in an old tube receiver with little IF filtering can be quite stupendous. The increase in the off-frequency attenuation and adjacent channel rejection can seem miraculous, with only a slight reduction in the audio output and an upward shift in the AGC threshold point. The signal-to-noise ratio is mainly established in the RF stage, so reducing the IF gain a bit has little effect on that, and the lower audio output is only evident from the fact that you have to turn the audio gain up slightly more on weak signals than you did previous to installing the filter, but now you can actually hear what they're saying!

This treatment is presently limited to receivers that have IFs of 455 kHz. Ceramic filters were, and maybe still are available for 450 kHz. However, if you don't mind a bit of extra work, there are ceramic resonators on a range of frequencies, which can be characterised and built up into ladder filters on other standard IFs, such as 560 kHz, 1 MHz and 2 MHz. I have done this in the past, and in one configuration the homemade AM filters have far more convenient impedances for tube circuits than the Murata and NTK 455 kHz ones – typically 10k ohms to 50k ohms. If I get a chance, I'll write something about them in a future ER article.

One word of warning, though, before I finish. There are old tube receivers that have excellent filtering for AM, and even though they might have an IF of 455 kHz you just wouldn't contemplate fitting a ceramic filter in them. I'm thinking of such receivers as the RCA AR88, which has extensive filtering for the wider bandwidths used on AM. There are other similar, fine receivers from the old days, and if you are unhappy with the performance of one of your old tube receivers, it's best to seek advice from someone who knows how these receivers are supposed to work when in A1 condition before you dive inside, and start modifying it. It may just be that the IF filtering is in need of alignment. However, primitive tube receivers with little IF filtering can really benefit from fitting a ceramic filter. **ER**

[Comments, from page 1]

dynamically select from among the entire range of frequencies available in a given band.

An important component of this change is consideration of the existing system of license classes and the desire to maintain motivation for basic licensees to improve their knowledge and skill. We propose retaining sub-bands that today recognize higher license class levels of achievement. In accord with the basic premise of this proposal, such sub bands by license class would also be permitted all modes of operation..."

I'll have more on this later.

Corrections

W2ZM's schematic on page 27 of ER #193 had errors not Bob's. Add a .002 µF, 2kV blocking cap between the plate of the PA and the output tank. Add 500k from the second audio grid to ground, and a 10µF electrolytic from the modulator filament CT to ground. Page 38, VE3CUI's schematic should have pins 4 & 5 of the 12AU7 grounded. 73, NØDMS